Darts Lab
Spacecraft Modeling and Simulation

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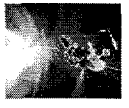
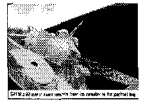
Mission Simulation Domains

SRTM
G&C Flex Dynamics Modeling

ST-3
Formation Control Analysis



Stardust
Optical Navigation
Test & Verification



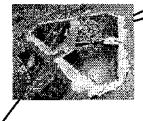
SCIENCE CRAFT

Mars Pathfinder
Cruise Modeling,
Test, Integration

CRUISE

ORBITERS

SIM
Flex Modeling &
Control Analysis



EDL

OPSP
FSW Development
and Testbeds

Galileo
Mission Testbed Upgrade
For Flight Operations

Cassini
Spacecraft Design &
Hardware-in-the-loop
Integration Testing

RENDEZVOUS

Mars 07
EDL Testbeds

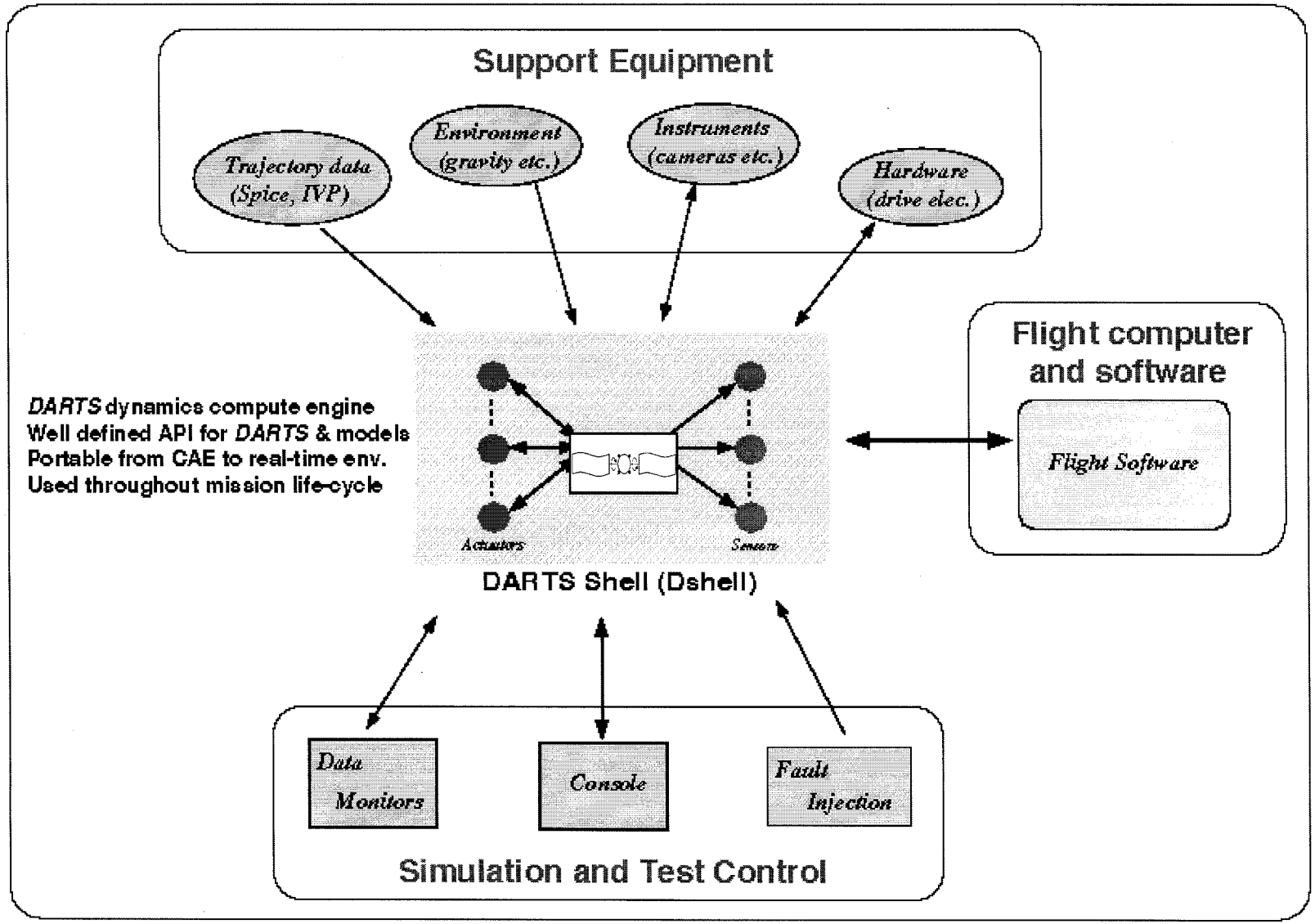
MER
Surface/Rover Ops.

ASCENT

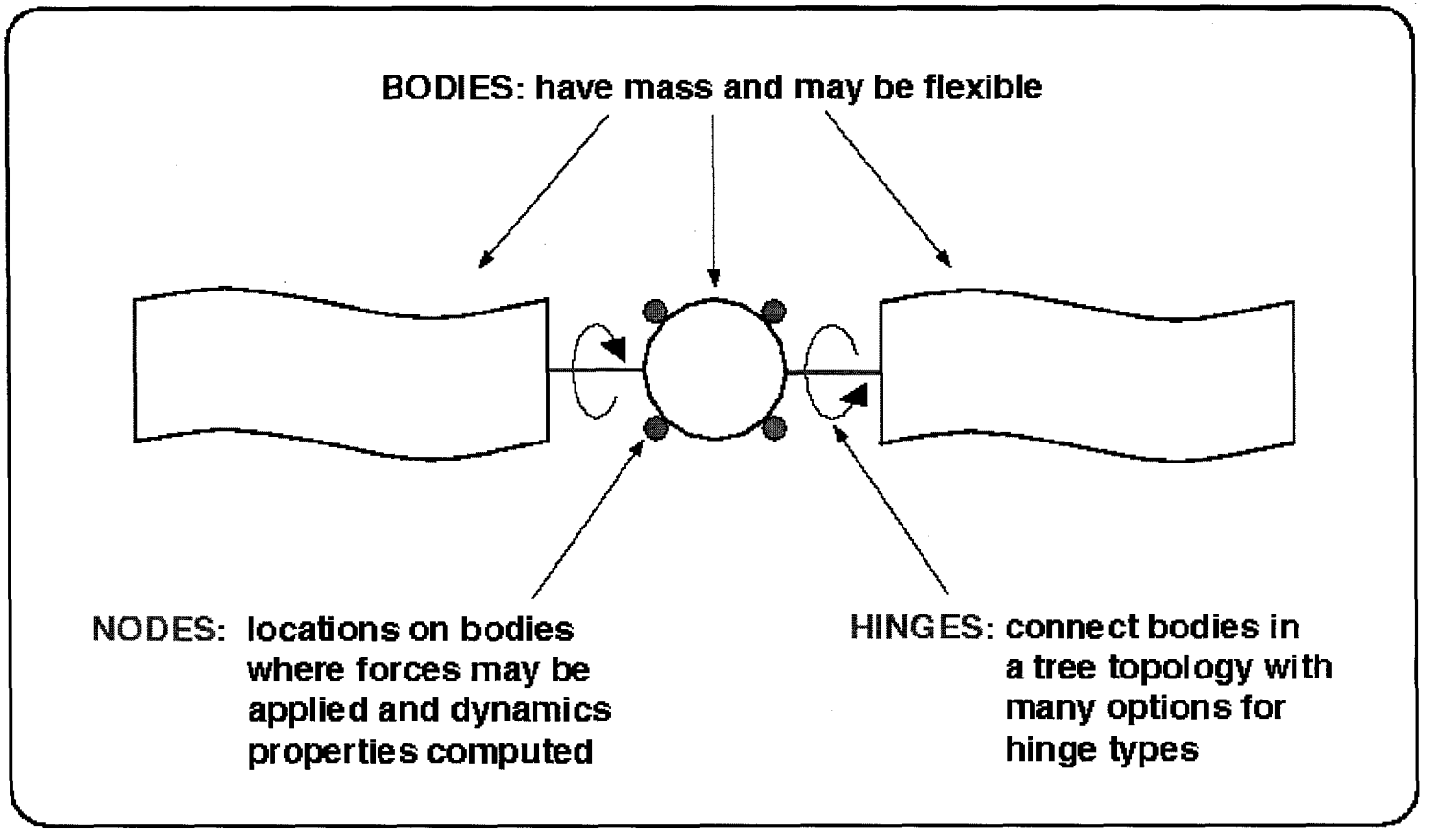
SURFACE

MSR
Rendezvous Modeling
& GNC Development

Dshell
Multimission Spacecraft Simulator



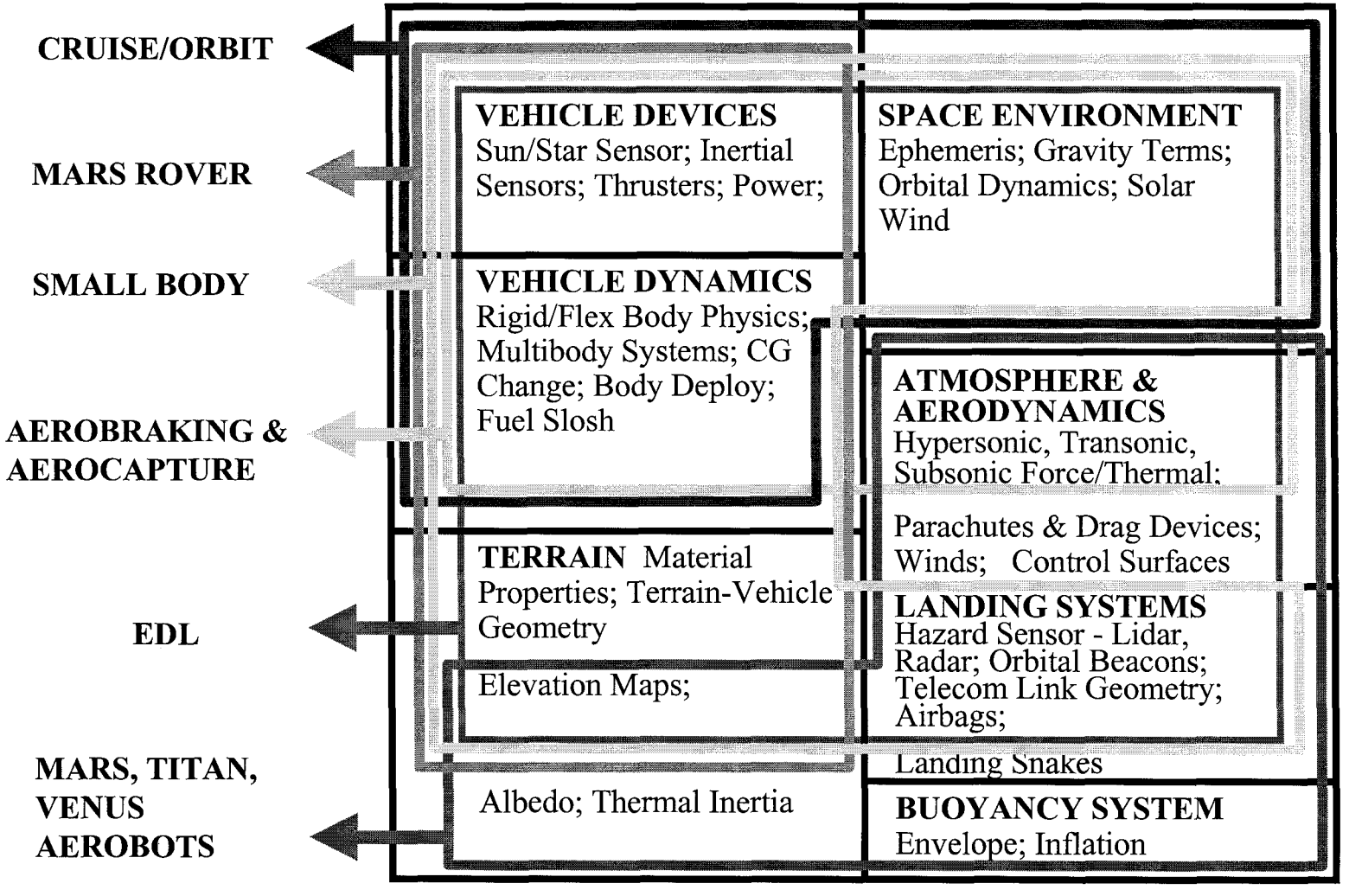
DARTS - Flexible Multibody Dynamics Compute Engine



* **DARTS** solves equations of motion for flexible multi-body system based on the dynamics properties of the bodies in the system and the forces applied to those bodies. Based on *Spatial Operator Algebra* state-of-the-art algorithms

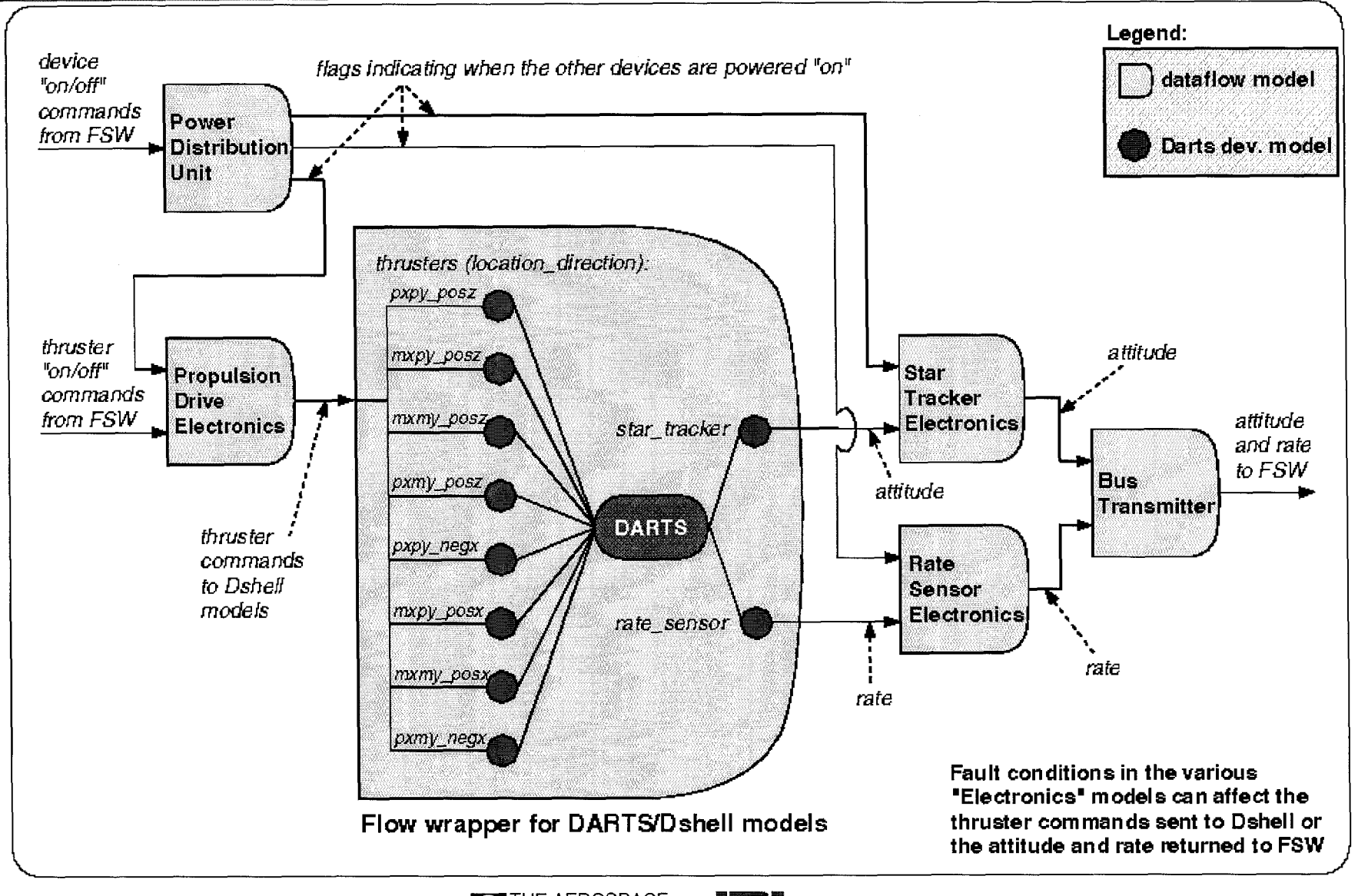
* **DARTS** includes interfaces for Dshell device models.

Layered Modeling Architecture

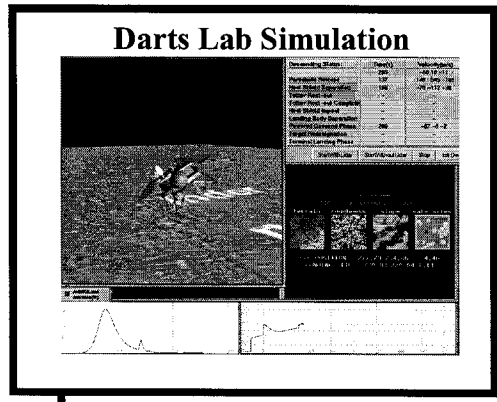


This approach facilitates model reuse and extensibility to new mission domains.

Run-Time Simulation Model Definition



Simulation Dimensions



Lifecycle Capability

- Analysis Env - Matlab/Simulink
- Standalone Mission Sim - Workstation
- Real-Time Testbed - VxSim/VxWorks
- Sub-system & System testbeds
- Hardware-in-the-loop/ATLO Testbeds - Bus I/F, Faults
- Operations Testbeds

Multiple Mission Domain Modeling

- Spacecraft Dynamics Models - Flex, Multibody
- Environment Models - Real/Fractal Terrain
- Planetary Models - Ephemeris, Spice kernels
- Num. Integrators - Runge-Kutta, variable step
- S/C Sensor/Actuator Models – Lidar, Thrusters, etc
- Simulation State & Parameters

Usability

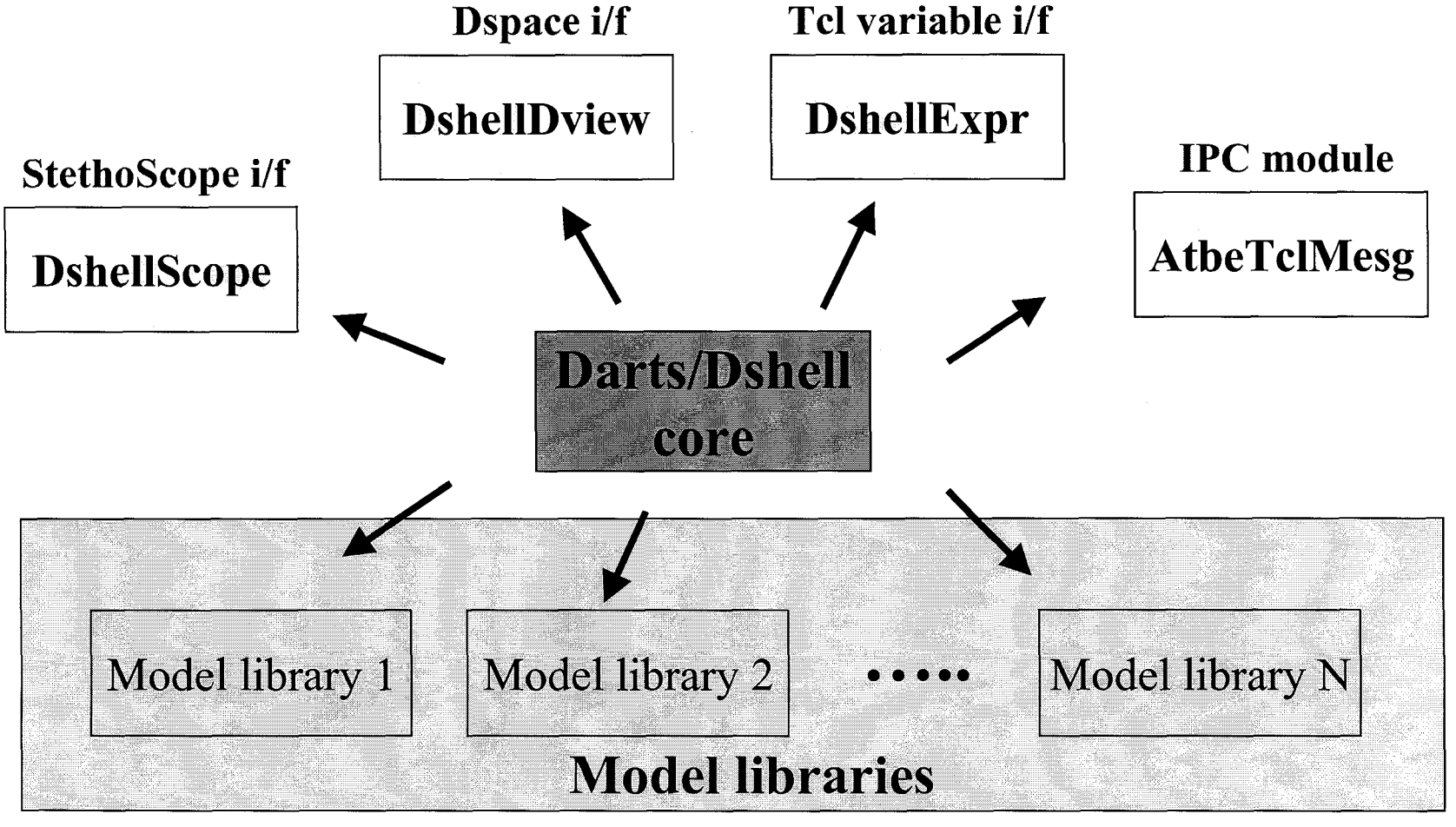
- Logging, Checkpointing
- Data Probe i.e. Peek/Poke
- Graphing/Visualization
- Verification utilities
- Fault injection interface
- Data monitoring
- Visualization

These are *"fault-lines"* where inadequate performance can cause costly testbed fragmentation.

Goal: ***Design and architect high-performance simulation capability which addresses these needs; is open/extendable to future domains; is multi-mission/reusable; is configurable***

Modular Run-Time Extension Architecture

Additional capabilities & extensions are ***"loaded"*** in as needed at run-time.



Specific Mission Domain Examples

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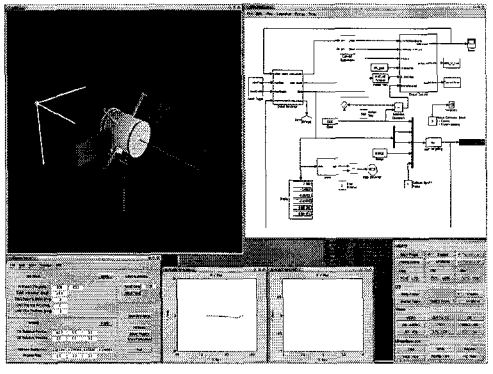
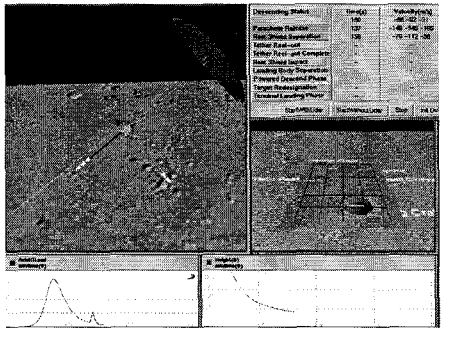
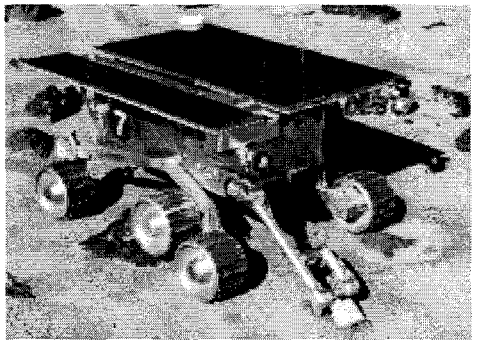


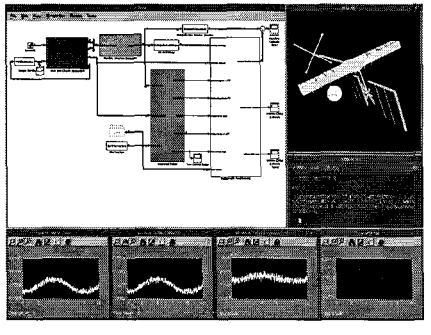
Rendezvous - Draper & in house G&C, Matlab/Simulink and stand-alone environments, planet & moon gravitational models



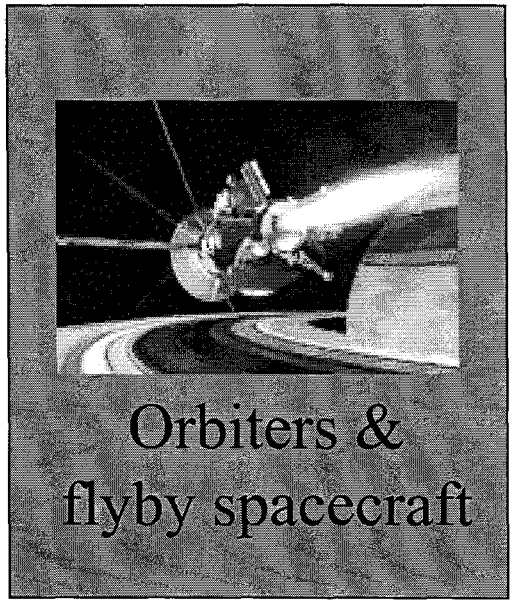
EDL - terrain models, LIDAR, s/c configuration changes, third party aero models, landing

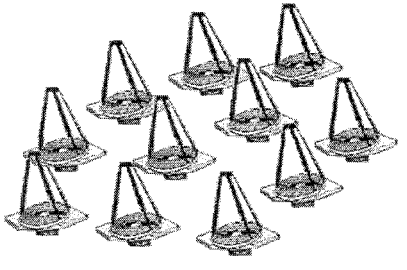


Rovers - terrain interactions, wheel/soil interactions, collision detection, new integrators



SIM - Large flex body dynamics, linear/nonlinear dynamics models, structural dynamics models, Matlab/Simulink environment





Formation Flying - Multiple coupled spacecraft, distributed sensors, communication delays, large dynamic range for sim. Data, distributed sim.

DSENDS - Entry, Descent & Landing Simulator

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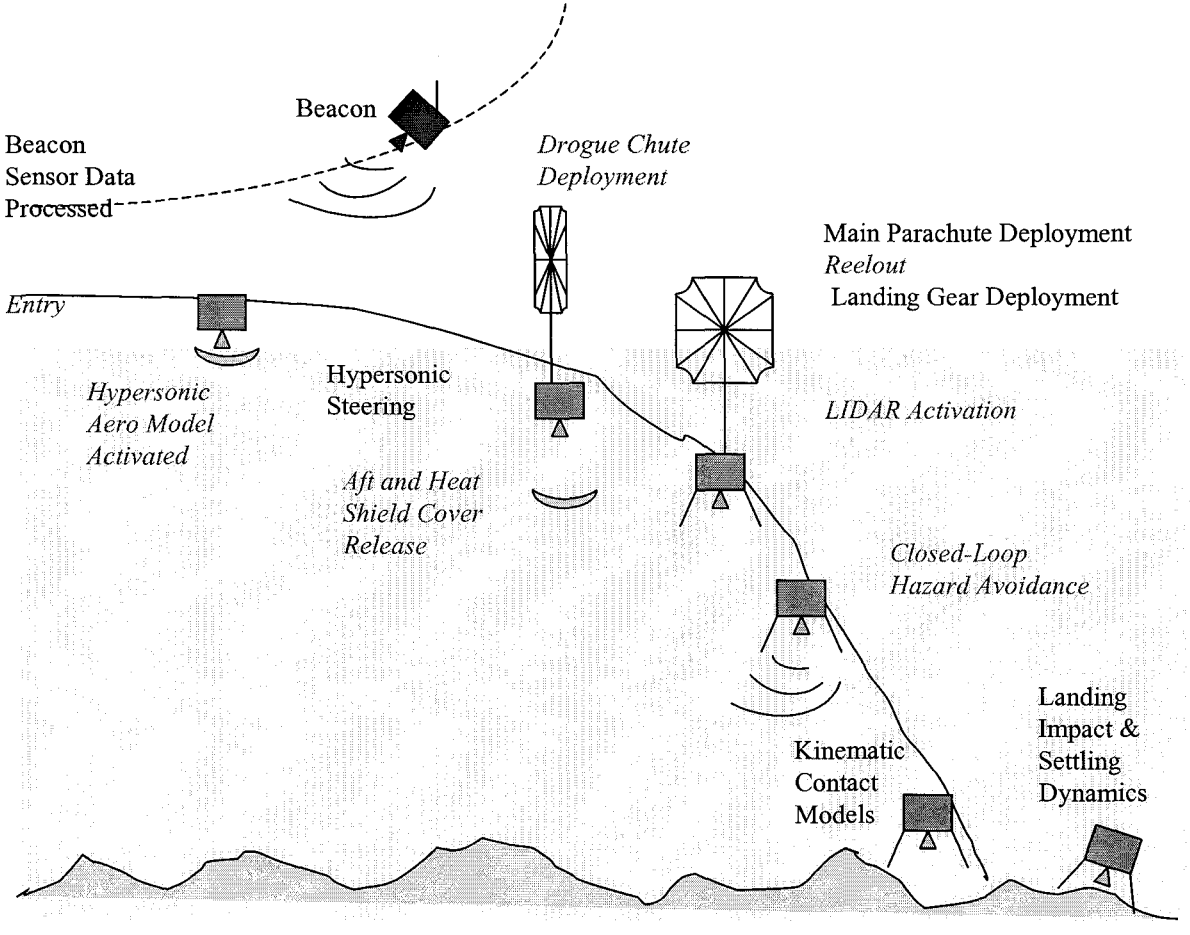

Simulation Demonstrates:

- *Multibody Dynamics*
- *Pendulum Dynamics*
- *CG Shifts*
- *Thruster Effects*
- Beacon Data
- *Shield/Cover*/Leg *Deploy*
- *LIDAR In-the-loop*
- *Terrain Models*
- Landing Geometry
- *Fuel Depletion*
- *Trajectory Propagation*
- *Closed-Loop Control*
- Landing Forces
- *Entry Aerodynamics*
- *Parachute Dynamics*

Red/Italic Coded Text Indicates Capability Being Exercised

DSENDS EDL Simulation

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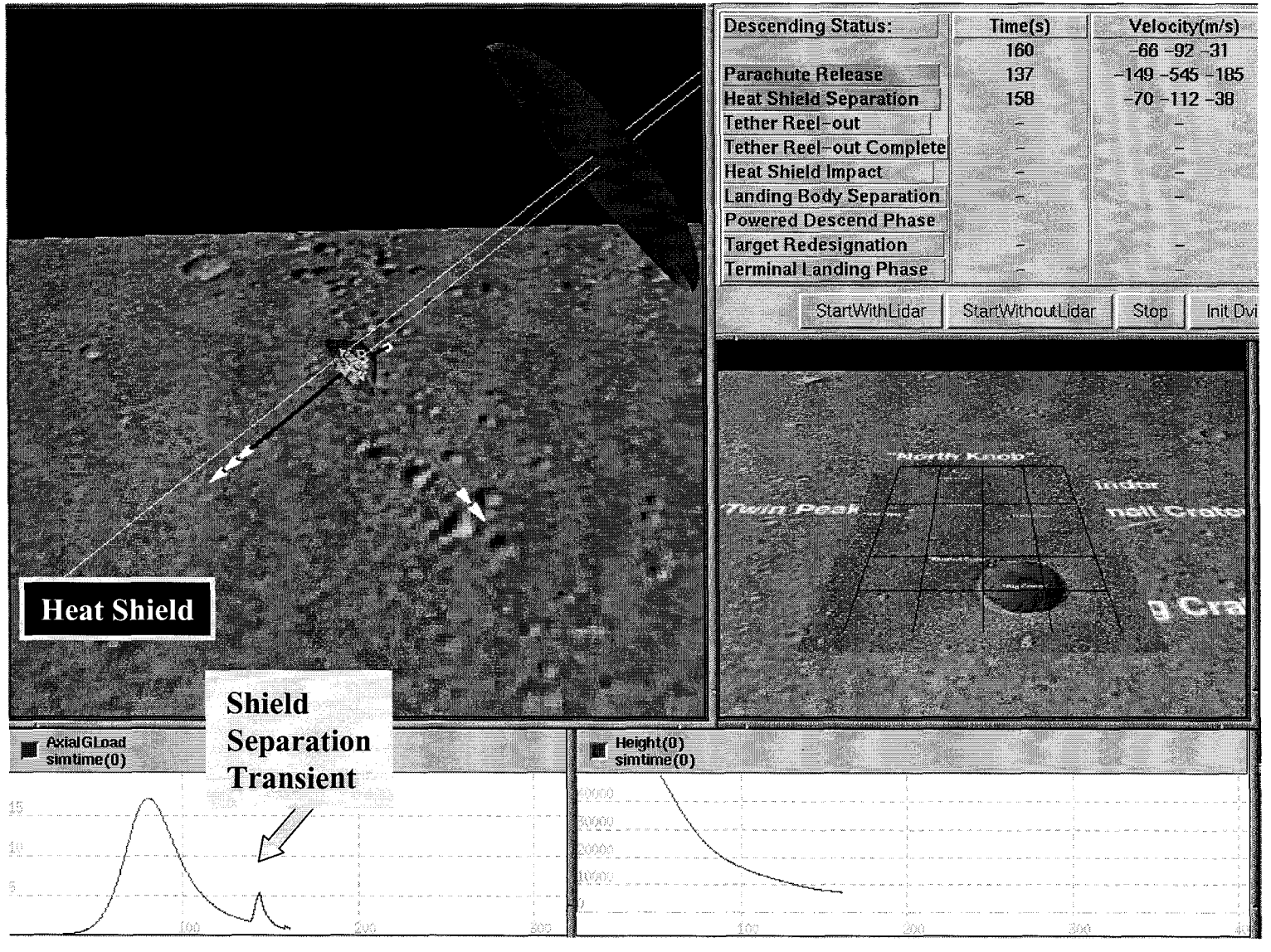

Mars Orbital Rendezvous Simulation

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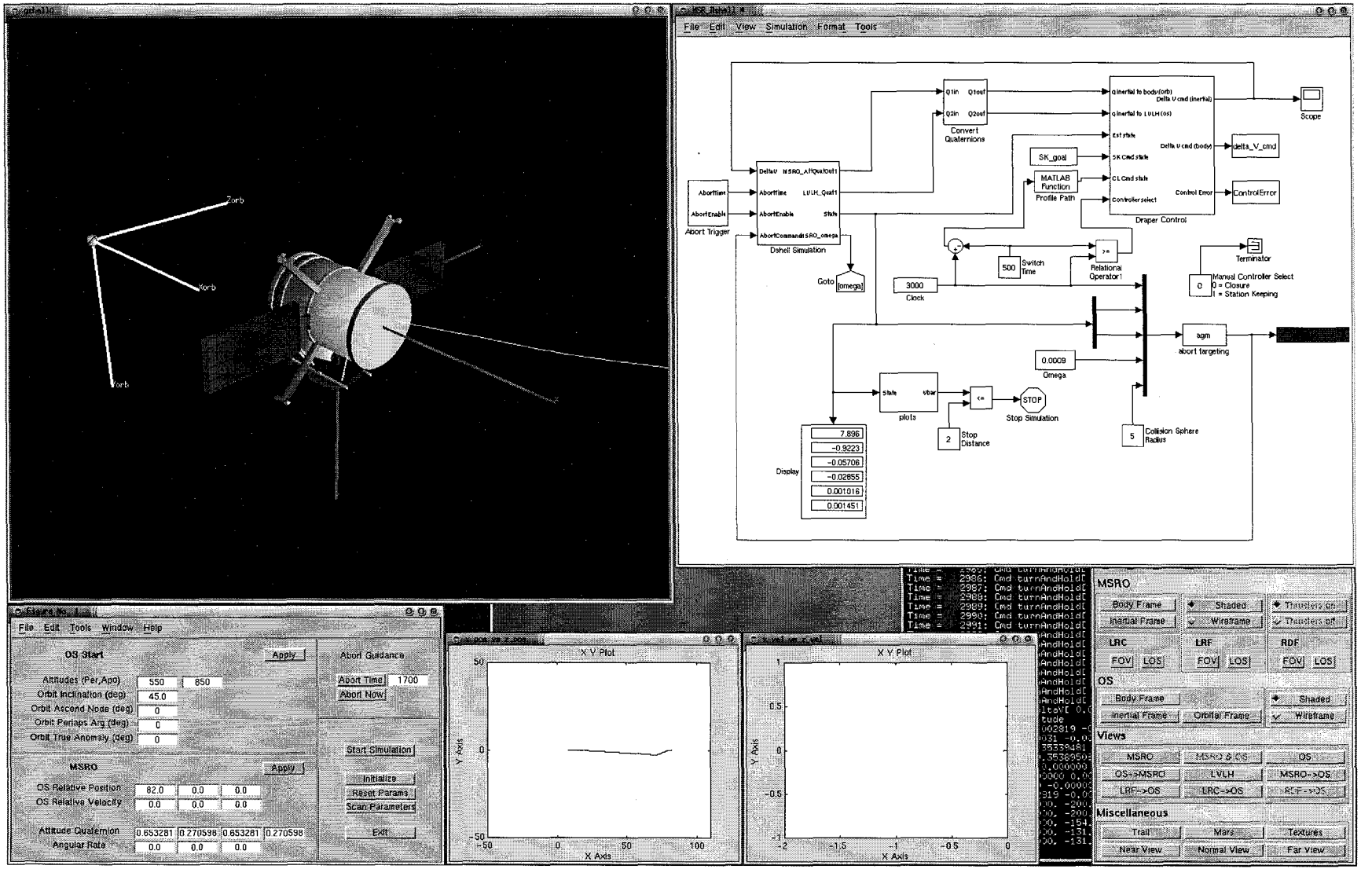
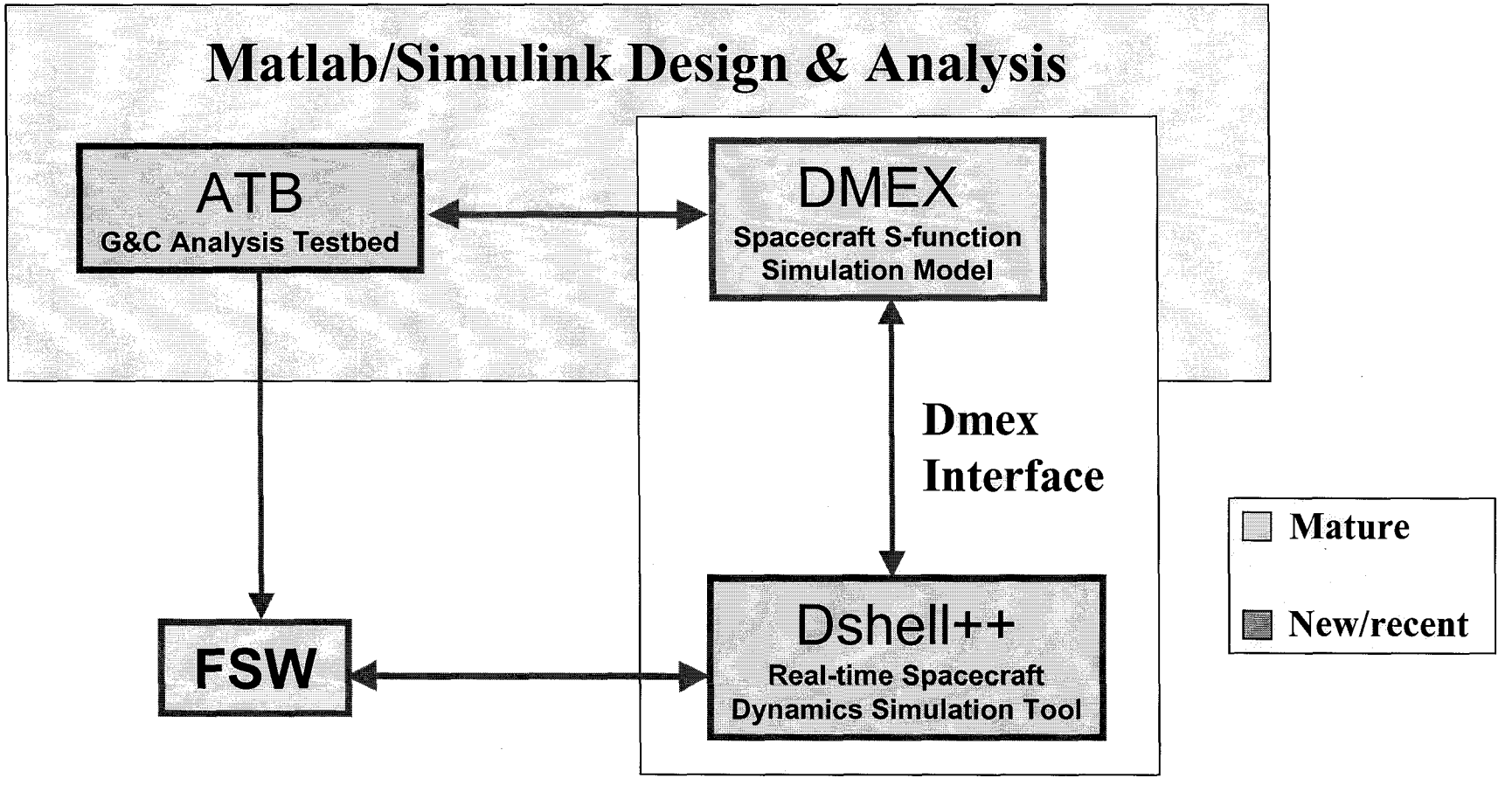


Dmex - Interface toMatlab/Simulink

To support **early workstation** and **later real-time** simulation needs, we have developed **Dmex** interface for embedding **Dshell** models in **Matlab/Simulink**.



Stand-Alone Closed-Loop Flight Software Simulation

SIM Instrument Modeling

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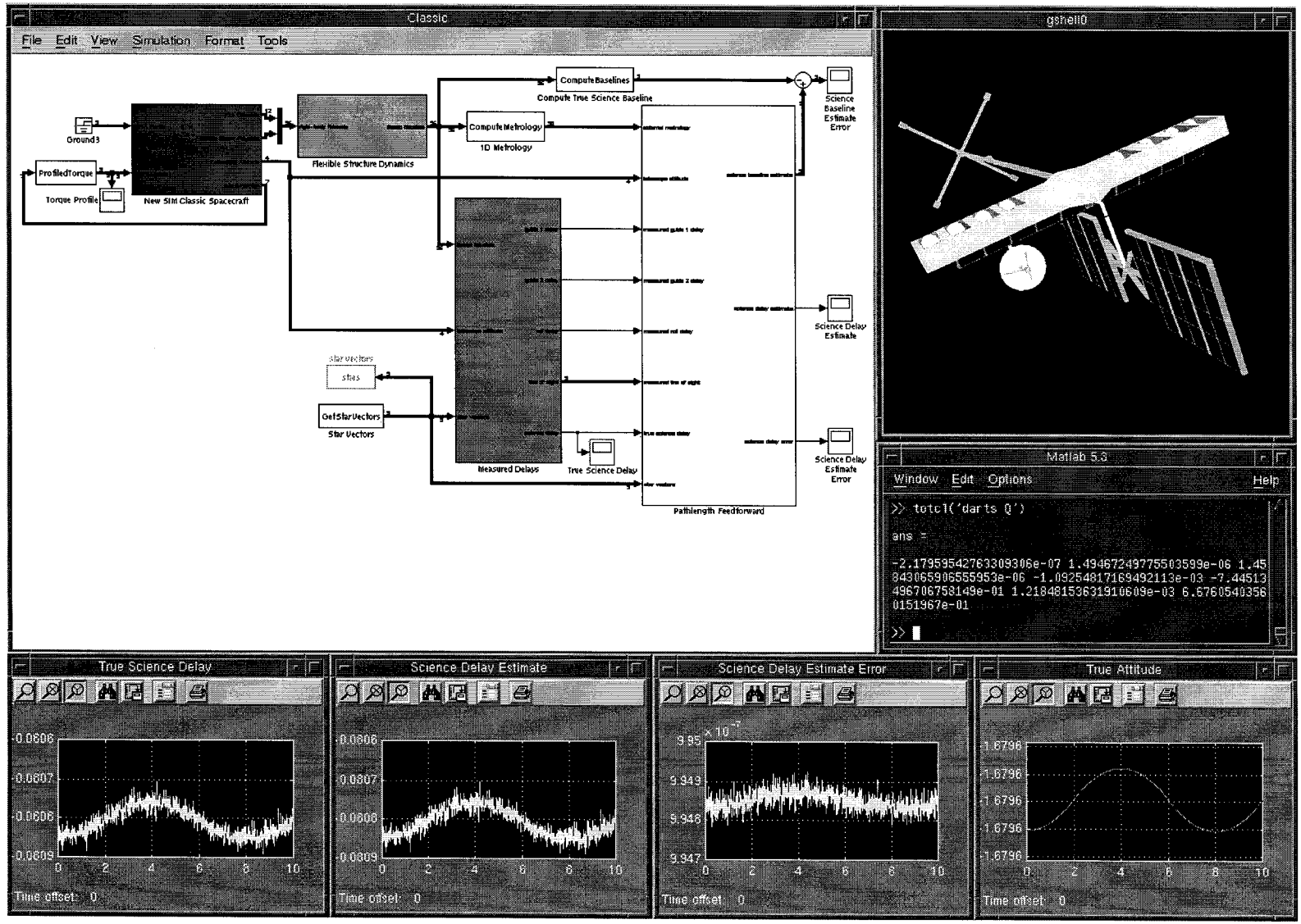
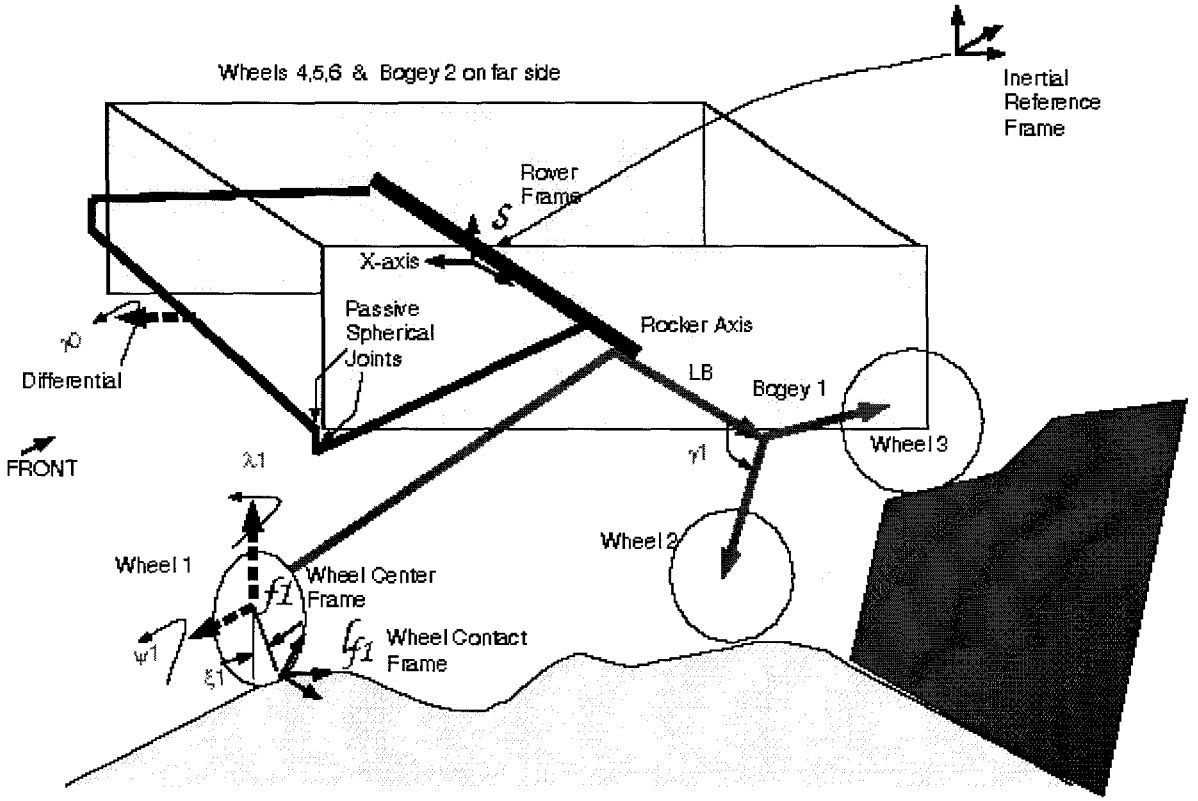


ROAMS Planetary Rover Simulator



- Rover kinematics
- Terrain
- Sensors - tilt, gyro, accelerometer
- Configuration Kinematics mobility algorithm
- Mobility dynamics
- Wheel models
- Wheel/terrain interaction
- Traction models
- Camera
- Hazard sensor
- Power - panel, battery
- Instrument arm

implemented

under development

Planetary Rover Mobility Simulator

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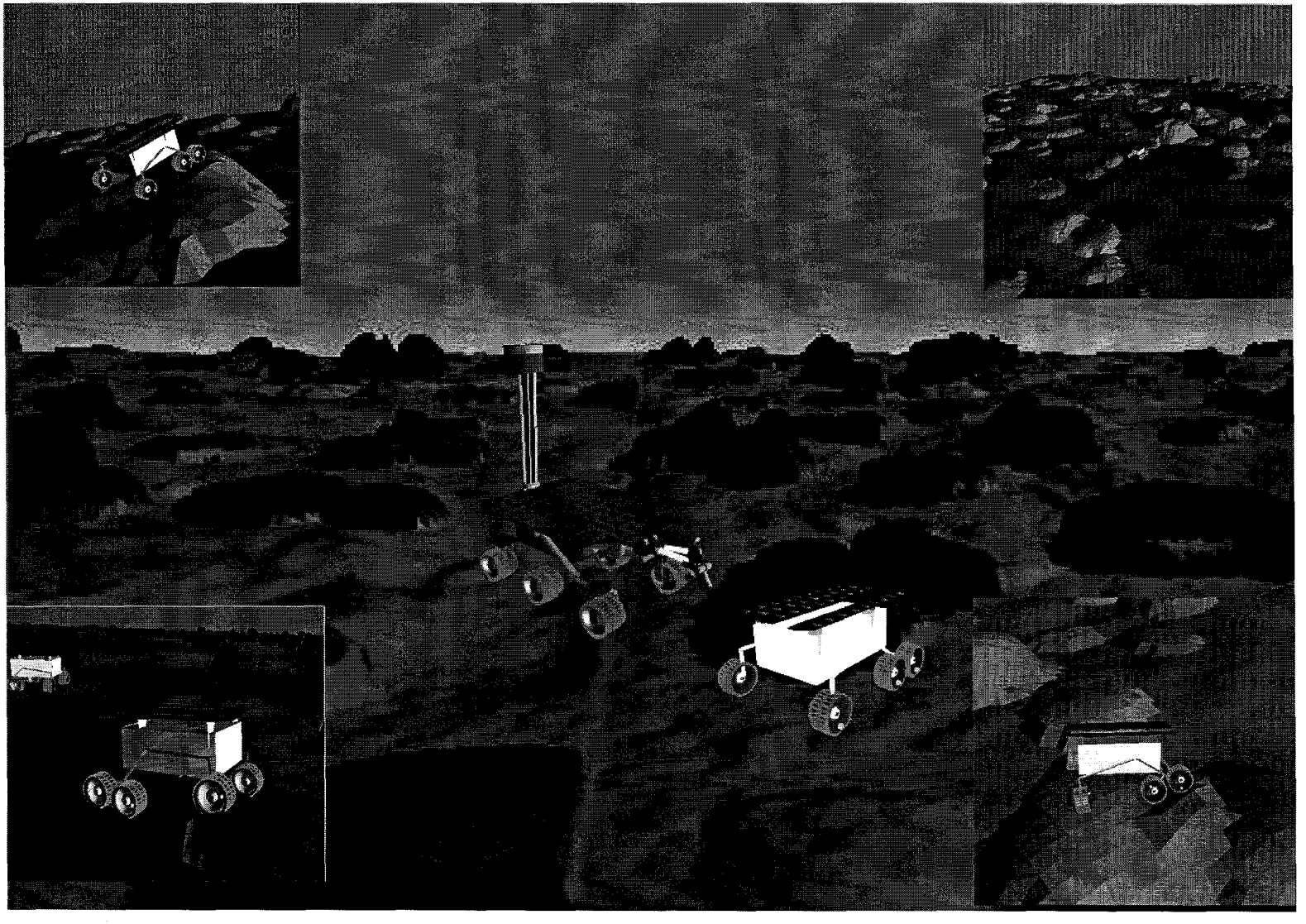

Mars Sample Return - Rendezvous Scenario

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- **Preliminary Rendezvous:**
  Search for the sample canister (OS)—which is ~15cm dia. and 3.6 kg mass—in a 600 km circular orbit (±100km 3s dispersion) and 45° inclination (±1° 3s dispersion) from the 250×1400 km orbit.
- **Intermediate Rendezvous:**
  Perform a series of maneuvers to alight its orbit node, inclination, and semi-major axis to match those of the canister's orbit.
- **Terminal Rendezvous:**
  Perform maneuvers from a co-elliptic orbit of several km below and hundred km behind OS to 80 m position on +V-bar and stationkeep for at least 2 orbits prior to close and capture operations.